In Situ Laser TOF-MS on Planets and Small Bodies

W. B. Brinckerhoff

The Johns Hopkins University Applied Physics Laboratory

OUTLINE

- 1. Landed planetary missions
- 2. TOF-MS for *in situ* analysis
- 3. Laser ablation method
- 4. Laser desorption method
- 5. Technology challenges and solutions

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1. Landed Missions: Why?

Certain measurement objectives can only be achieved by landing (or at least touching) a planetary surface.

- Comparative, local, and microscopic sample studies
- Quantitative (or even semi-quantitative) composition
- Minor and trace element geochemistry
- Presence and complexity of organic molecules
- Mineral grain distributions
- Subsurface sampling and depth profiling
- Whole rock or ice sample return (reconnaissance/acquisition)

and even ...

Detection of extinct or extant life

Instruments must form an integrated suite.

- Capabilities and limitations are dictated by specific mission
- Balanced set of experiments to study surface composition

Bulk Local Micro (NB: level of sample handling affects accessible scale)

Mineralogy Elemental Isotopic Organic UV/Vis/IR imaging, Raman, XRD GCMS, APXS, GRS, LIBS, LDMS, SIMS (essentially all MS, precision-dependent) Aq Chem, GCMS, LDMS/MALDI, SIMS

This is only a small subset of *in situ* experimental techniques!

Major Surface Mission Targets [*]	Flyby	Orbiter	Descent/ Surface	Sample Return	Humans
Earth/Moon	<i>√</i>	✓	1	1	<i>✓</i>
Near Earth Asteroids (NEA)	NEAR, DS-1	NEAR	NEAR (ad hoc)	MUSES-C	Armageddon (movie)
Comets	ICE, VEGA, Giotto, D. Impact, CoNTour	Rosetta	Rosetta/Roland	Stardust, (CNSR)	Deep Impact (movie)
Mercury	Mariner 10	Messenger, Bepi Colombo	Bepi Colombo		
Venus	Mariner 2,5,10, VEGA	Pioneer Venus, Venera, Magellan	Pioneer Venus, VEGA, Venera		
Mars & moons	Mariner 4,6,7	Mariner 9, Viking, MGS, MOd, MEx, Nozomi	Viking, Pathfinder, MER, MEx	(hard but doable \$10 ⁹)	(very hard but doable \$10 ¹⁰)
Main Belt Asteroids	Galileo, NEAR	(under study)			
Europa	Voyager, Galileo	EO	EL	Don't even ask.	
Ganymede	Voyager, Galileo				
lo	Voyager, Galileo				
Callisto	Voyager, Galileo				
Titan	Voyager, Cassini		Huygens, TOE		
Triton	Voyager				
Pluto/Charon/KB	(PKE)				

* *Example* missions, plans, and concepts. *Not* meant to be comprehensive!

1. Landed Missions: Asteroids

What can asteroids tell us about the formation and evolution of the solar system, and of Earth in particular? From which asteroids do we have meteorite samples? Do asteroids hold "untold riches" for humankind? Is an asteroid going to blow us away one day?

Several objectives at asteroids are addressable with mass spectrometry of near-surface materials.

- Bulk elemental analysis for comparison to meteorites
- Discriminators: Mg/Si, Al/Si, S/Si, Ca/Si, Fe/Si, Fe/Mn
- Minor and trace compounds
 - calibrate remote sensing data
 - complements Raman and other mineralogy probes
- Inventory of volatile and refractory species
- Isotope systematics and anomalies
- Presence and nature of organic molecules

1. Landed Missions: Mars

Several objectives at Mars are addressable with mass spectrometry of near-surface materials.



Life

- analyze rocks, fines, and ices for organics and key elements
- combine refractory and volatile analyses (energy sources)
- "biomarkers" may be very small scale, low abundance, high mass

Climate

- early atmosphere preserved in surface composition
- isotopic trends capture long-term conditions

Resources (Geochemistry)

comparative composition (many samples); geochronology?